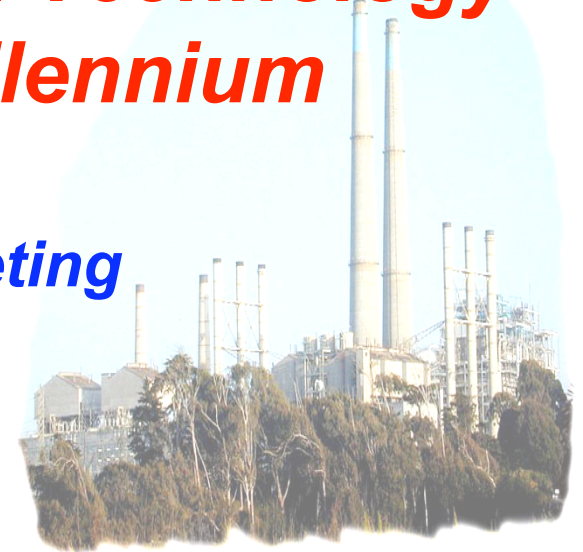


# ***Alternate Energy Research and Technology Challenges in the New Millennium***

***4<sup>th</sup> Indo-US Roundtable Meeting  
NIAS, Bangalore, India  
21-23 Sept, 2010***



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Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>SEP 2010</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Alternate Energy Research and Technology Challenges in the New Millennium</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Research Laboratory Washington, DC 20375</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>See also ADA560467. Indo-US Science and Technology Round Table Meeting (4th Annual) - Power Energy and Cognitive Science Held in Bangalore, India on September 21-23, 2010. U.S. Government or Federal Purpose Rights License</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>19</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			





# Global Issues

- • Energy ←
- Water
  - Environment



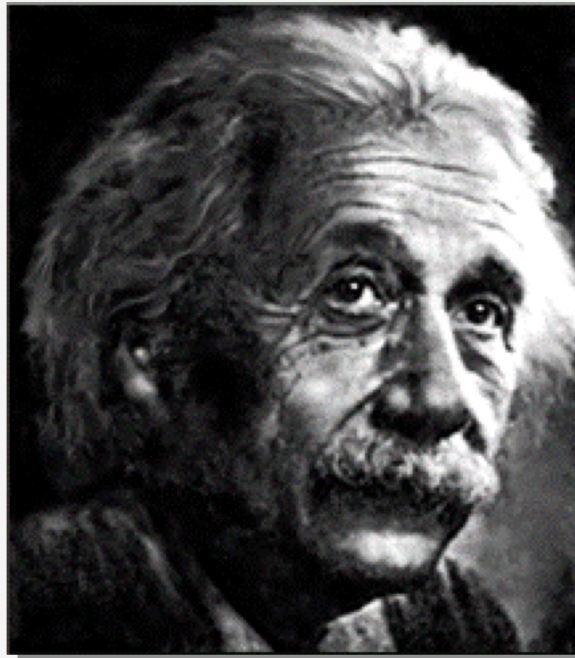
# The Energy Challenge Our Generation's Challenge



When asked shortly  
after WWII:

---

**“Prof Einstein,  
what do you see  
as the greatest  
threat to  
mankind?”**



His prompt reply:

---

***“Exponential  
growth.”***





# **Future of Energy After Oil**

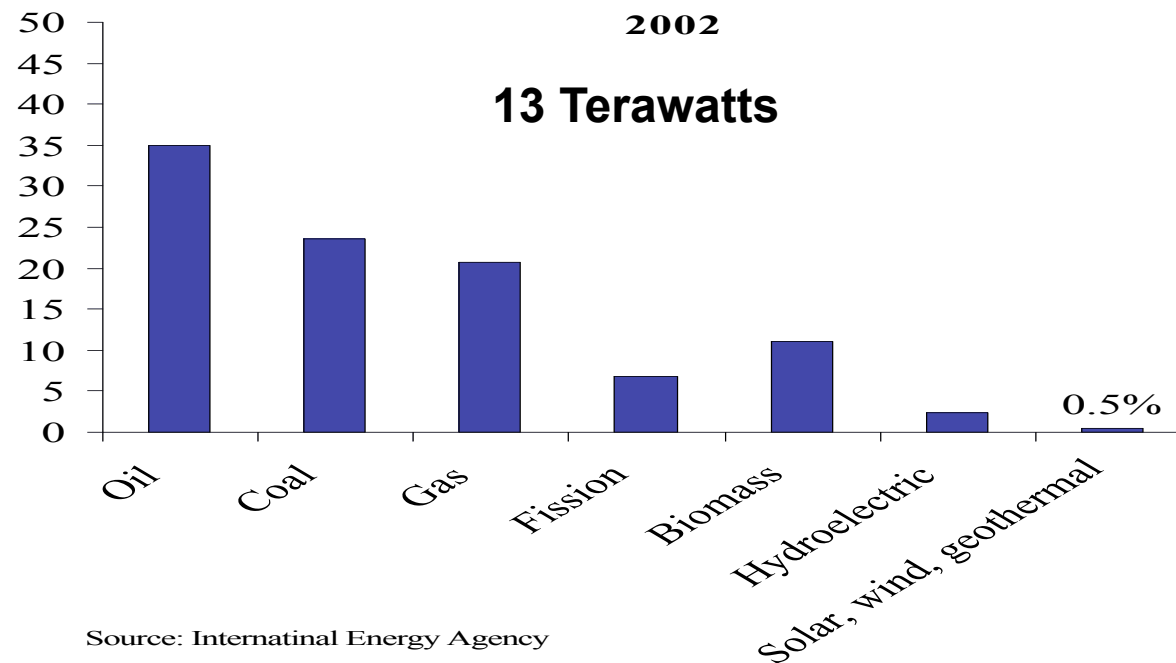
## **The Problem**



# The ENERGY REVOLUTION (The Terawatt Challenge)



## Sources of Energy Supply - Worldwide



Source: International Energy Agency





# Setting the Stage: A Global Overview

- Consider in 1900 less than 1 million barrels of oil per day vs. today at 85 million barrels per day
- “Optimistic case for out put of 100 million barrels per day could outstrip supply before 2020”

C. de Margerie, TOTAL

- “By 2010 nearly 40% of the world’s daily oil output will have to come from the fields that have not been tapped or even discovered.”

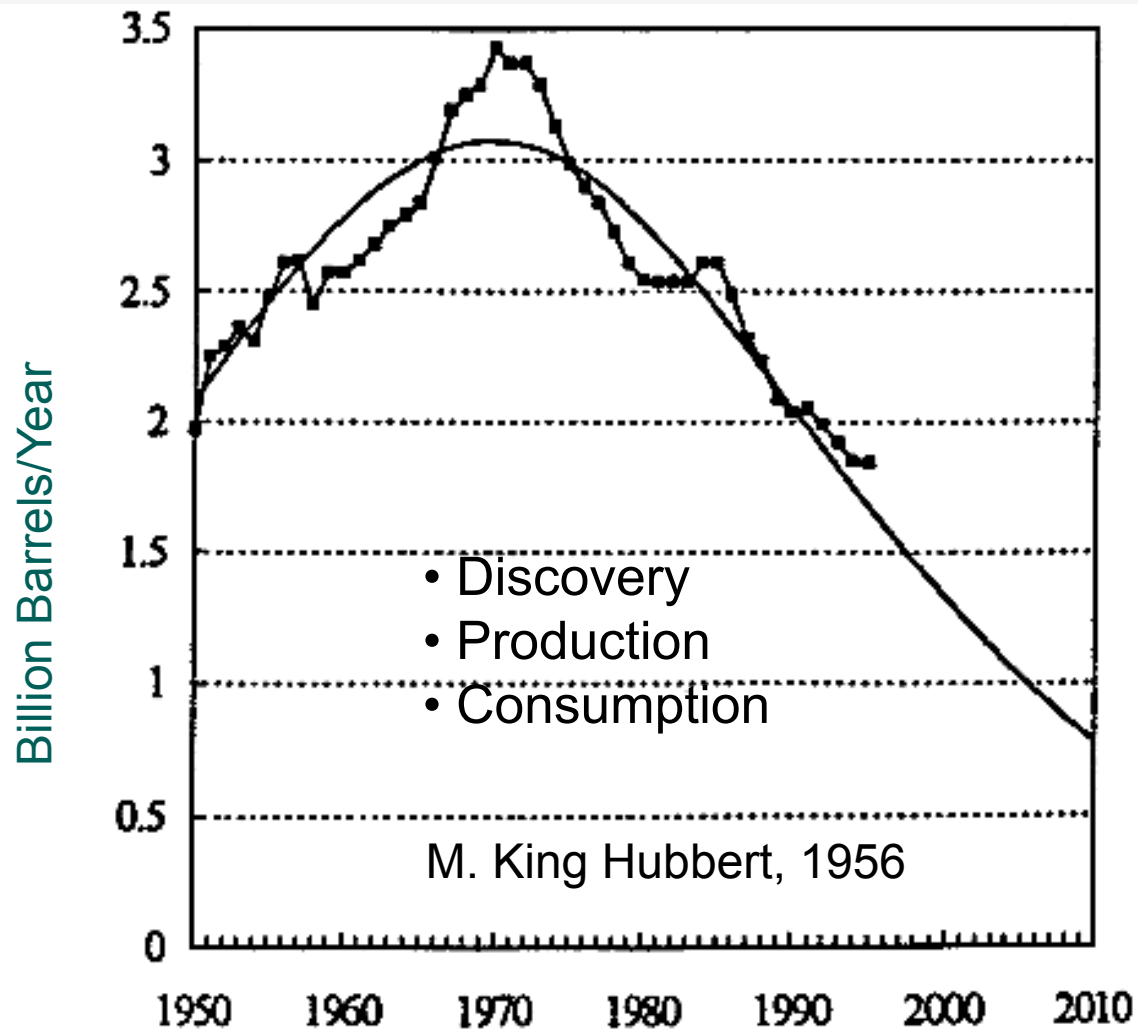
J. Mulva, ConocoPhillips

- “By 2015 we need to find, develop and produce new oil that is equal to 8 out of 10 bbl being produced today.” President Exxon Mobil 2003





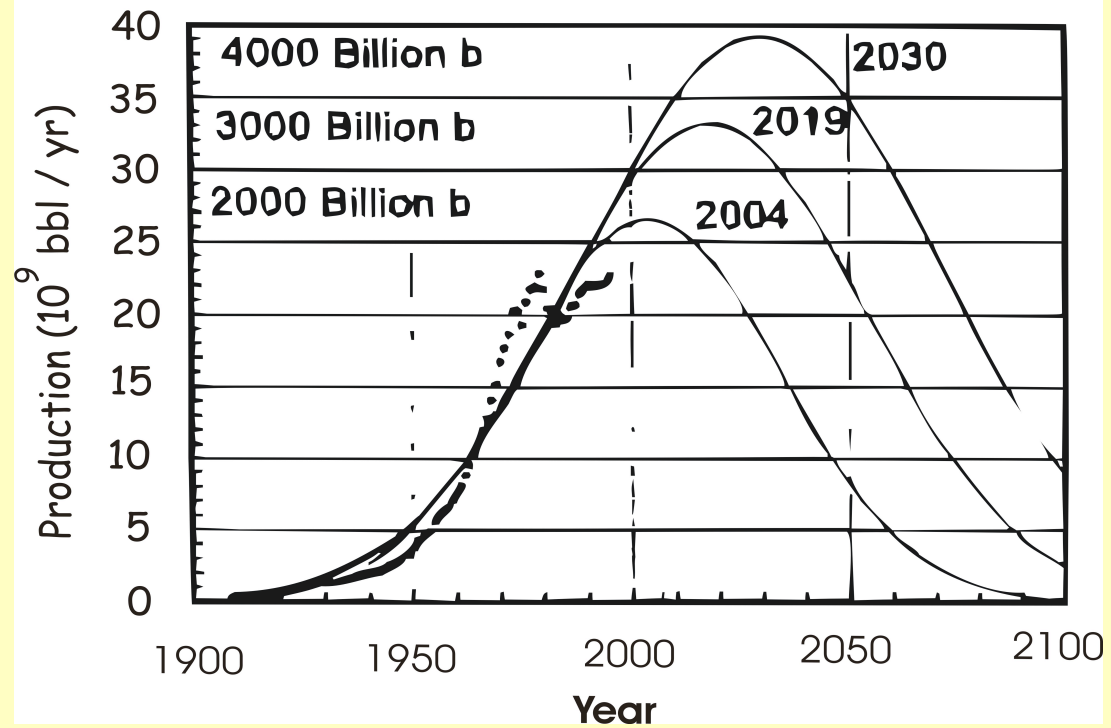
# Crude Oil Production in the Lower 48







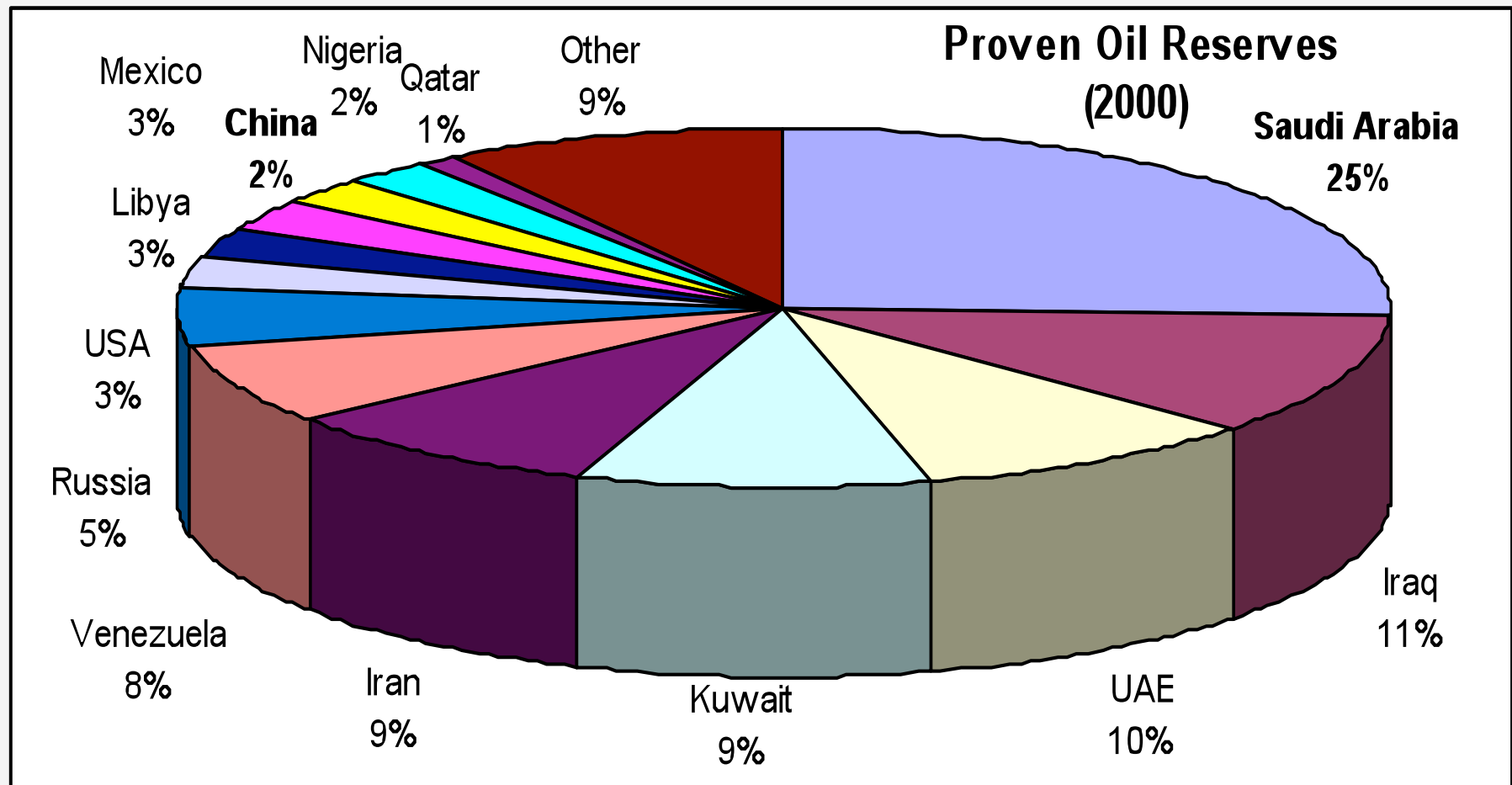
## World Oil



Deffeyes, Hubbert's Peak, 2001



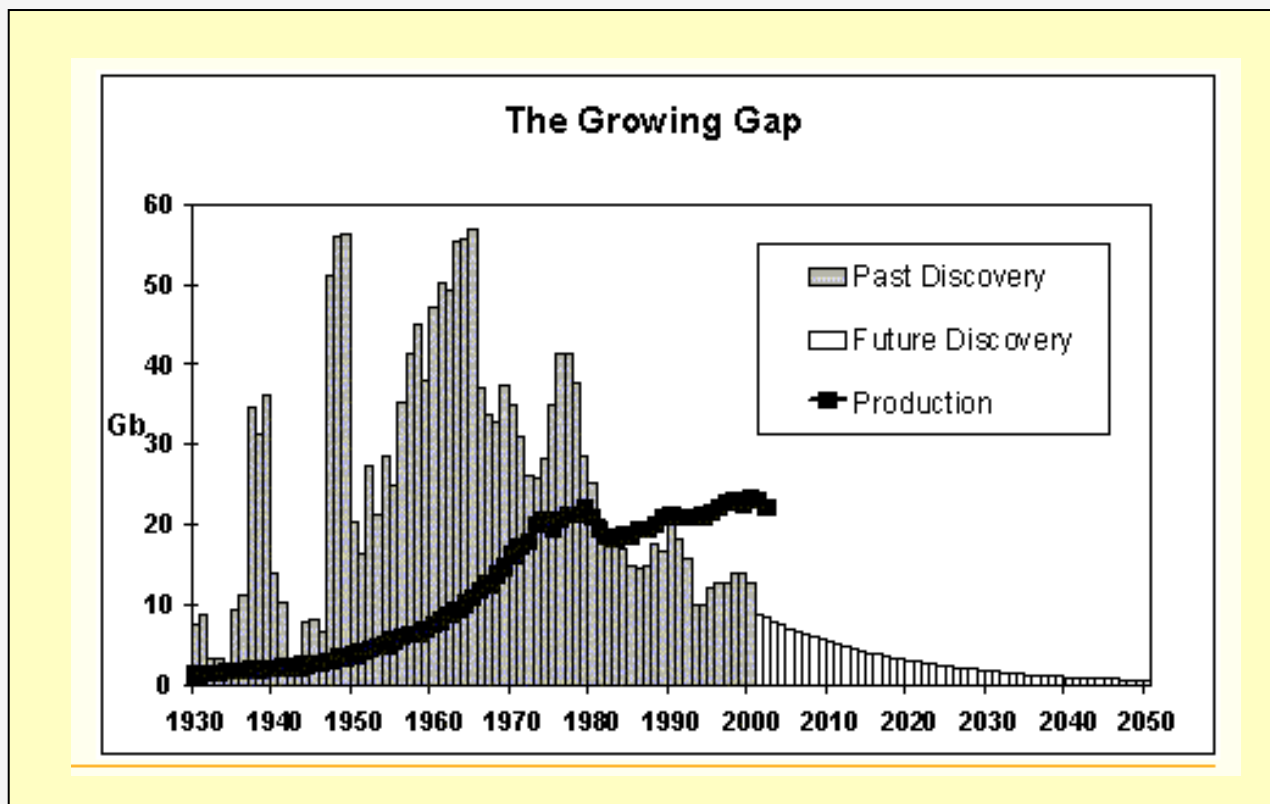
# World Proven Oil Reserves







# Depletion of Oil Reserves



*World oil reserves accumulated since 1930 are now being depleted. Industrial growth in Asia will accelerate the depletion*

The Coming Oil Crisis, Colin J. Campbell





# Alternatives (Renewables and nonrenewables)

- **Conservation / Efficiency**

- not enough

## Renewables

- **Biomass** -- large land mass, cost?, aviation?
- **Hydrogen** -- cost? safety? Beyond horizon for large scale use
- **Wind** -- commercial, not enough
- **Nuclear Fusion** -- technology challenges, cost? Beyond horizon
- **Solar terrestrial** -- commercial, large land mass, cost?
- **Geothermal** -- not enough
- **Wave** -- not enough, coastal issues
- **Ocean thermal** -- confined to tropical / equatorial regions, cost?
- **Hydroelectric** -- not enough
- **Synthetic fuel** -- technology challenges

## Non Renewables

- **Clean Coal / CTL** -- sequestration?, cost?
- **Nuclear Fission** -- radioactive waste?, cost??
- **Natural Gas** -- resource and usage limits
- **Oil shale** -- Technology? Environment? Cost?
- **High energy density fuel** -- research challenges
- **Methane Hydrates** -- clean and in abundance

(• Potential candidates for Navy / DOD)





# **Biomass: A Potential Renewable Energy Source**



# Biomass: A Potential Energy Resource



- The oldest known energy source since the discovery of fire
- World's 4th largest energy source (47 quads/year;  $13.6 \times 10^{15}$  watt hr;  $47 \times 10^{15}$  BTU)
- Domestic Biomass Source for Energy
  - Agricultural Waste
  - Forestry Waste
  - Municipal Solid and Industrial Waste
  - Energy Crops (Grown for Fuel)
- Goals for Energy Contribution from Biomass by 2020 (NREL/DOE)
  - 10% Transportation Fuels
  - 5% Electric Power Production
  - 18% Chemicals and Materials



*Robert Armstrong, NDU Report*

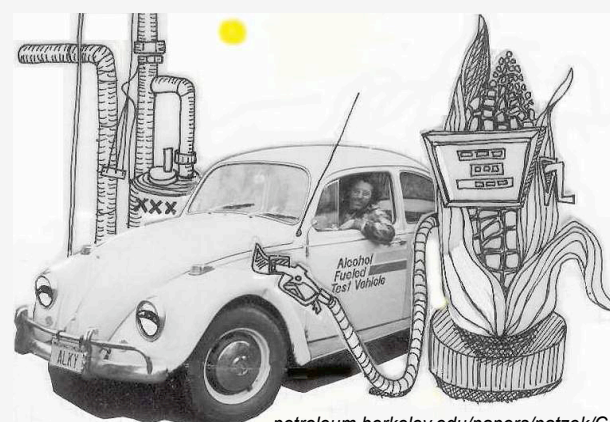


# Range in Biofuel Production



Feed Stock	~ Gal Oil / Acre / Yr
Corn	350
Soybeans	48
Safflower	83
Sunflower	102
Rapeseed	127
Oil Palm	635 (2 crops)
Sugar Cane	662 (2 crops)
Cassava	410
Sweet Sorghum	374
Algae*	1000-5000**
Camelina*	75-100
Cyanobacteria*	700?
Jatropha*	125
Switchgrass*	Low?

A comprehensive study is needed to evaluate investment, production, cost and future implications



[petroleum.berkeley.edu/papers/patzek/CRPS416-Patzek-Web.pdf](http://petroleum.berkeley.edu/papers/patzek/CRPS416-Patzek-Web.pdf)



[http://oakhavenpc.org/cultivating\\_algae.htm](http://oakhavenpc.org/cultivating_algae.htm)

\*Non food crops

\*\* requires massive CO<sub>2</sub> injection for higher gallon number





# Alternate renewable fuels From biomass (diesels & alcohols)

## Feedstocks

Algae

Vegetable Oils



Animal Fat

(Conoco Philips and Tyson Foods)  
(Neste Oil)

Multiple Biomass  
(Municipal Waste)

Corn / Sugar Cane

## Processes

**Esterification**  
(methanol, Strong Base)  
 $\text{CH}_3\text{OH} + \text{NaOH}$

**Hydro-treating**  
(Hydrogen)

**Biomass to Liquid**  
(BTL Gasification)  
(formation of syngas)

**Hydrolysis/  
Fermentation**

## Products

**Biodiesel**  
Fatty Acid Methyl Ester (FAME)

**Green  
diesel**

**Fischer-Tropsch (FT)  
diesel**

**Ethanol/C2+  
Alcohols**

## Problems

**Stability**  
(microbial, emulsions,  
solvation)

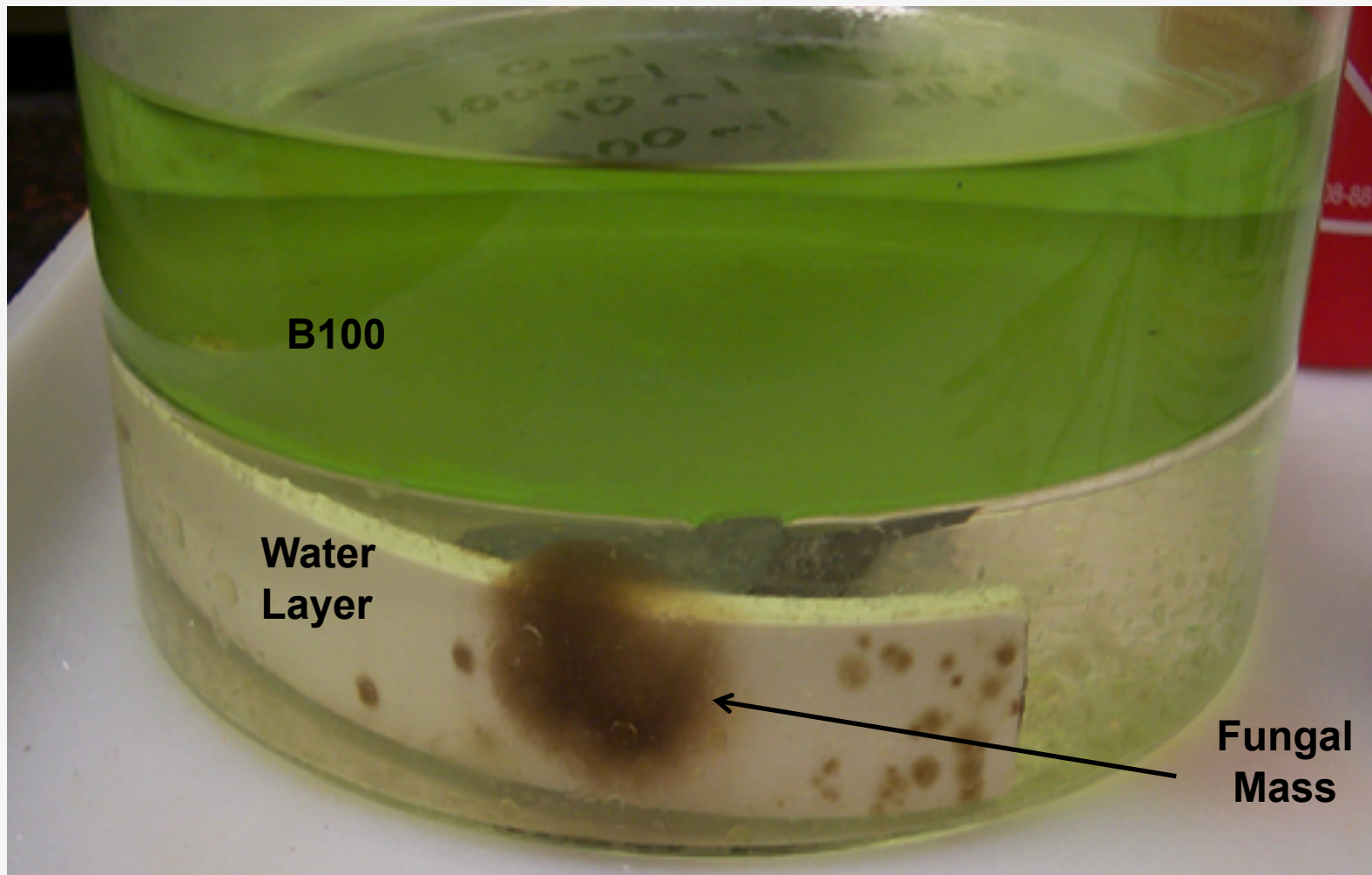
**Stability**  
(Meet Navy  
Specifications??)

**Navy  
Specification  
Testing**

**Navy  
Specifications**  
(Flashpoint, Energy  
Density)



## Demonstration of Biofouling in a Diesel Fuel /Water Mixture





# Biodiesel provides carbon source for microbial growth resulting in sulfide production and corrosion



No Sulfide  
Production

Sulfide  
Production

No Sulfide  
Production

Biodiesel  
Persian Gulf SW  
Carbon Steel Coupon



Sterilized Persian Gulf  
Seawater + Biodiesel

Natural Persian Gulf  
Seawater + Biodiesel

Natural Persian Gulf  
Seawater



# Hydrocarbon Yields from Corn / Sugar cane

## Gasoline Gallon Equivalent



Fuel Type	BTUs/gal	Gal. Equivalent
Gasoline, regular unleaded	114,100	1.00
Diesel (typical)	129,800	0.88
Methanol	56,800	2.01
Ethanol	76,100	1.50



- Low energy density
- Low flash point
- Hygroscopic
- Energy Input exceeds output
- Unsuitable for naval use



# Switchgrass to Ethanol



- A perennial grass native to the Great Plains
- Grows in marginal land
- Needs seeding once / decade
- Cultivation requires fertilizers (~ 100 lbs N / acre) and irrigation
- Low yield in marginal land
- Needs higher cost enzymes for bioreactors, cost / gal about that for corn